# *AST3-NIR (KISS)*

## *PROJECT DEFINITION PLAN*

## *(SEPTEMBER 2015)*

## *REVISION 0.11*

| Rev. No. | Author | Reviewer | Approved (AAO Director) | | Approved (External Client) | |
|---|---|---|---|---|---|---|
| | | | Name + Signature | Date | Name + Signature | Date |
| 1 | Jon Lawrence | Julia Tims | Warrick Couch | | Jeremy Mould | |

## Acronyms

| | |
|---|---|
| AAO | Australian Astronomical Observatory |
| AAO Facility | 105 Delhi Road, North Ryde, NSW 2113 |
| AIT | Assembly, Integration & Test |
| ANU | Australian National University |
| ARC | Australian Research Council |
| AST3-NIR | Antarctic Schmidt Telescope #3 – Near Infrared |
| CIT | Caltech Institute of Technology |
| DoS | U.S. Department of State |
| FDR | Final Design Review |
| GLS | GL Scientific |
| ICD | Interface Control Document |
| IPEV | Institut polaire français (French Polar Agency) |
| ITAR | International Trade in Arms Regulations |
| KISS | $K_{dark}$ Infrared Sky Survey |
| LIEF | Linkage Infrastructure Equipment Fund |
| MIA | Multi-Institute Agreement |
| NIAOT | Nanjing Institute of Astronomical Optics and Technology |
| NSF OPP | US National Science Foundation Office of Polar Programs |
| PMO | Purple Mountain Observatory |
| PRIC | Polar Research Institute of China |
| SAIL | Swinburne Astronomical Instrumentation Laboratory |
| SUT | Swinburne University of Technology |
| TAMU | Texas A&M University |
| UNSW | University of New South Wales |
| USyd | University of Sydney |

## Reference Documents

| | | |
|---|---|---|
| 1 | LE150100024 | LIEF Application |

| | | |
|---|---|---|
| 2 | AST_SPC_001 | Master Requirements Document |
| 3 | AST_PLN_003 | AST3-NIR Export Plan (Rev. 2) |

# 1 PROJECT DEFINITION

This document provides the project definition plan for the AST3-NIR Antarctic instrument project, funded via a successful ARC LIEF grant. The plan includes a description of the instrument high level aims and objectives, the key project personnel, the proposed concept, budget, and schedule, and an overall assessment of the key risks at the initialisation phase of the project.

## 1.1 Project Aims

The primary aims of this project are:

- To conduct a deep high-cadence wide-field Kdark infrared sky survey (KISS) from Antarctica;
- To enhance the Australia/China/US collaboration in Antarctic astronomy; and
- To gain knowledge on the operation of and procurement procedures for infrared detector arrays to be used in Antarctica.

## 1.2 Project Objectives

The specific project objectives are to:

- Design and build a wide-field K-band imager for the AST3-NIR telescope (the AST3-NIR telescope is being designed and built by NAOIT);
- Integrate and interface the imager with the AST3-NIR telescope (location for integration to be determined); and
- Support commissioning activities (in-person and/or remotely) for the AST3-NIR telescope + instrument in Antarctica.

## 1.3 Science case

Science cases (explained in more detail in the LIEF application) include: supernovae, exo-planets, variable stars, reverberation mapping, gamma-ray-bursts, young stellar objects, young massive stars, cosmic infrared background.

## 1.4 Instrument Ownership

The instrument developed and all materials procured for the instrument project will be owned by SUT and made available on-loan to the project team for the duration of the project.

## 1.5 Project Stakeholders

The LIEF proposal Investigators are:

- Jeremy Mould (SUT) as Lead Investigator
- Karl Glazebrook (SUT) as Chief Investigator
- Michael Ashley (UNSW) as Chief Investigator
- Michael Burton (UNSW) as Chief Investigator

- Lifan Wang (PMO/TAMU) as Partner Investigator
- Anna Moore (CIT) as Partner Investigator
- Jon Lawrence (AAO) as Partner Investigator
- Peter Tuthill (USyd) as Chief Investigator
- Mike Ireland (ANU) as Chief Investigator.

## 1.6 Project Team

The AAO project team and interfaces are defined in Figure 1- below.

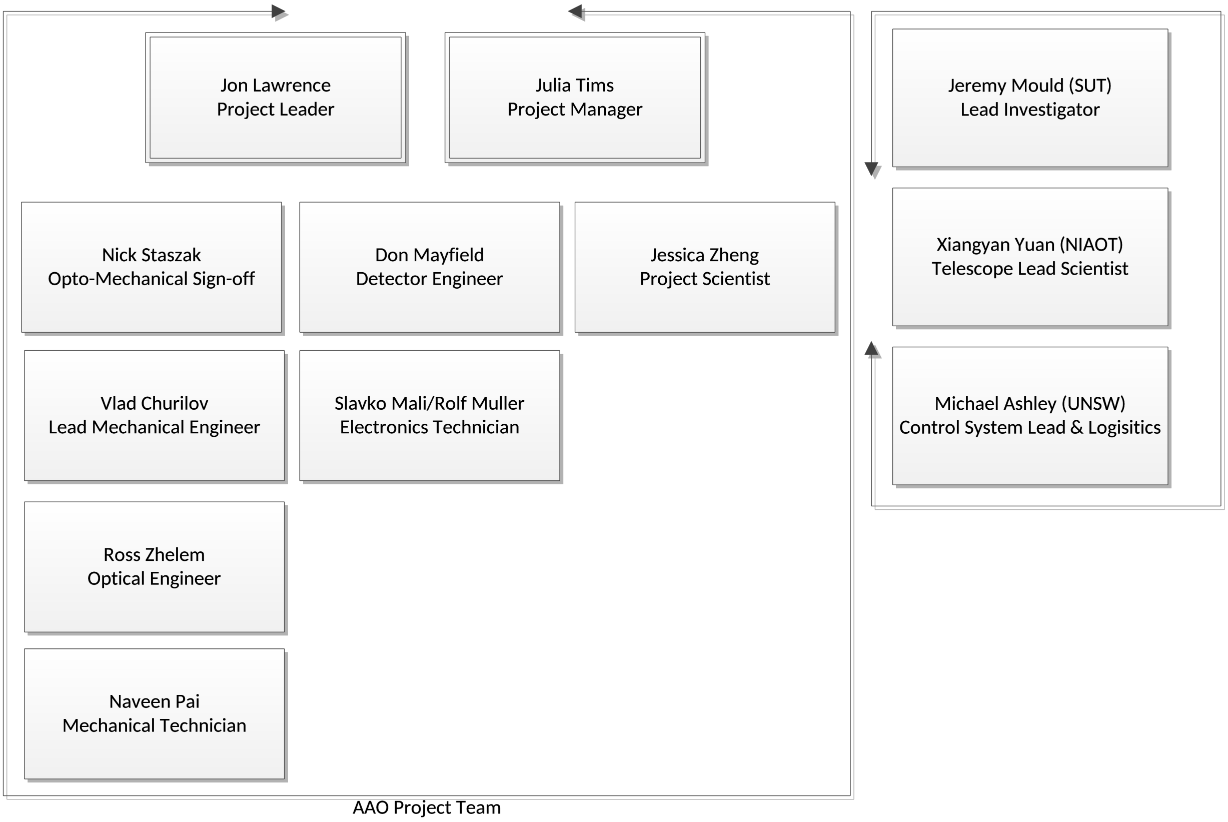



**Figure 1- Project Team**

# 2 INSTRUMENT (CAMERA) DEFINITION

## 2.1 System Requirements

The system requirements for the telescope and instrument are defined in *"AST_SPC_001"*.

High Level System Requirements will require sign-off by the SUT Lead Investigator prior to preliminary design in accordance with the schedule defined at 3.2 of this document.

## 2.2 Concept Design and Definition

a) The instrument will consist of a 2.5 µm cut-off HgCdTe detector array, mounted in a cryostat with window, internal baffling, $K_{dark}$ filter, a cold stop, and magnifying optics;

b) The camera will mount to a flange on the AST3 telescope providing access to the Naysmth focal plane;

c) The instrument includes a control system that will interface with the AST3 telescope and the PLATO Supervisor computer.

### 2.2.1 Optical Layout Concept

The optical concept is shown in Figure 2- below.

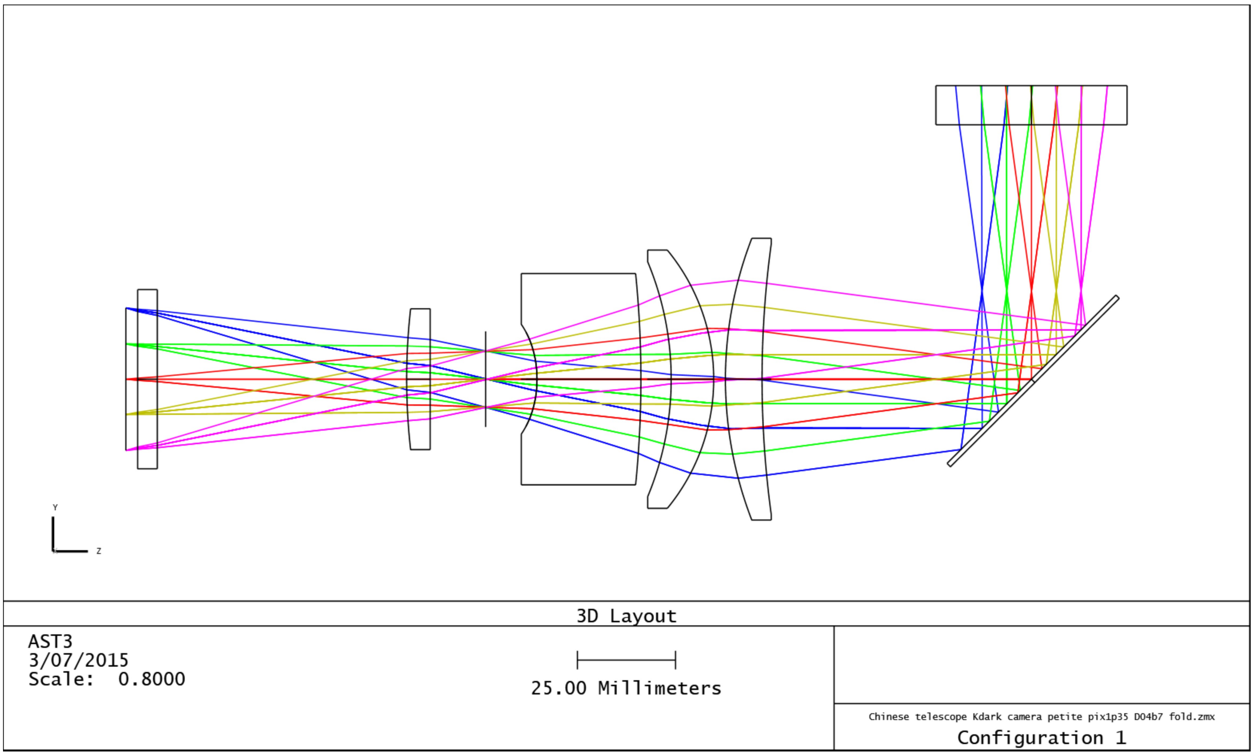



**Figure 2- Optical Camera Layout Concept**

### 2.2.2 Mechanical Layout Concept

The mechanical concept is shown in Figure 2- and Figure 2- below.

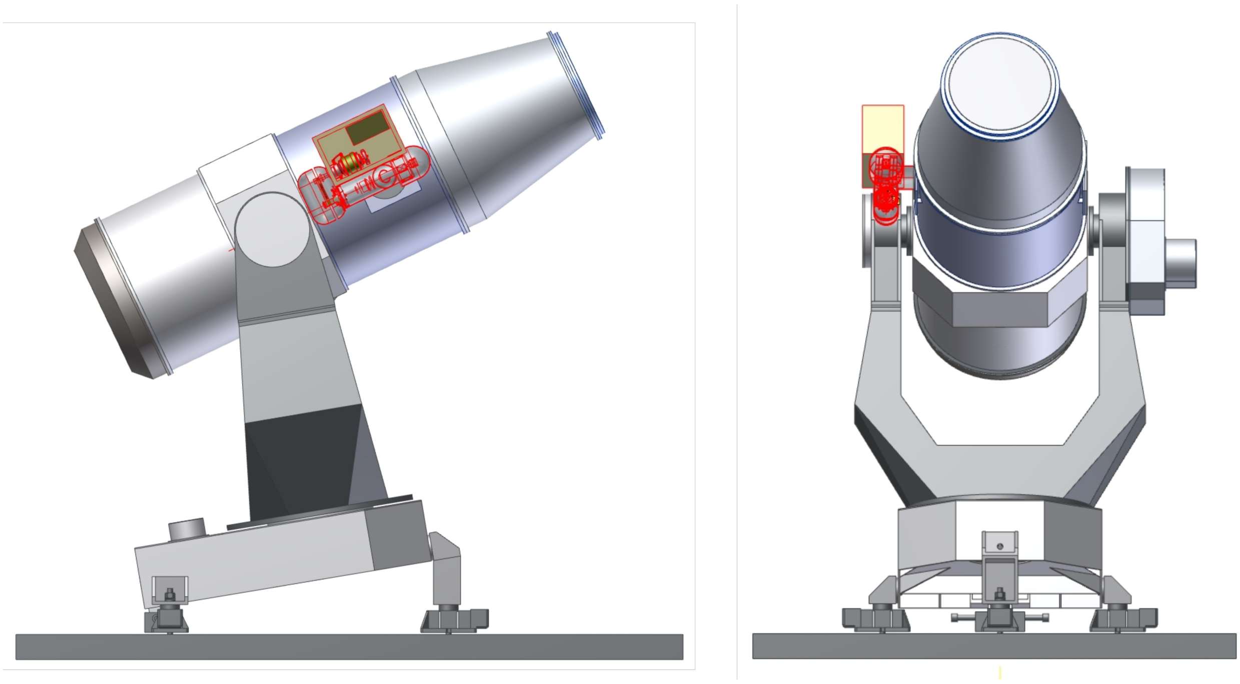
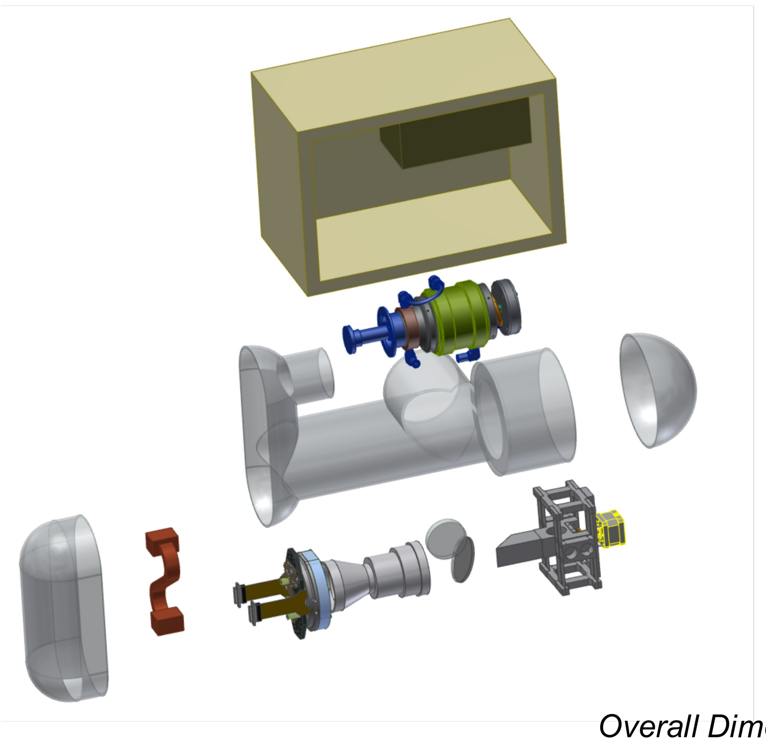
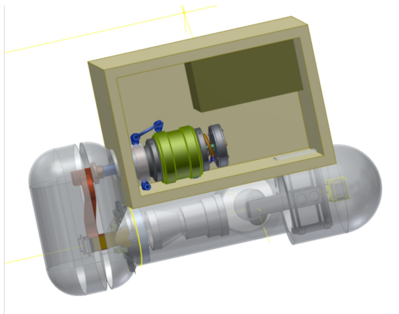


**Figure 2- Camera Concept Location w.r.t. Telescope**





*1 – Detector assembly*
*2 – Optical Camera*
*3 – mirror*
*4 - Vacuum window*
*5 – Focusing Mechanism*
*6 – Cold Strap*
*7 – Cryocooler (Sunpower Stirling)*
*8 – Electronics Thermal Cabinet*
*9 – Vacuum vessel*

*Overall Dimensions, approx: 700 x 500 x 300*
*Mass approx 30 kg*

**Figure 2- Mechanical Concept**

## 2.3 Instrument Sub-Systems

The instrument is broken down into the following eight sub-systems.

#### 2.3.1 Systems & Management

Includes project management, systems engineering and instrument requirements management, team meetings and travel to China.

- AAO's Project Leader and Project Manager will manage the overall camera project;
- The Lead Investigator is responsible for sign-off on the High Level Requirements;
- The Lead Investigator is responsible for developing the science teams and survey program.

#### 2.3.2 Interfaces

Interfaces include development of interface specifications and drawings (ICDs) for the:

- Telescope;
- Detector; and
- Electronics/control systems.

#### 2.3.3 Opto-Mechanics

Includes the optical design layout and tolerances and camera lens mechanical mounts.

#### 2.3.4 Detector & Controller

Includes the design and procurement for the detector and the detector controller.

#### 2.3.5 Cryostat System

Includes the design and procurement for the cryostat: body, feedthrough, vacuum and cooling sub-systems.

#### 2.3.6 Control System

Includes the design, procurement, and assembly for the instrument controller.

#### 2.3.7 Software

Includes the development and testing of low level control software and high level instrument control and interface software.

#### 2.3.8 AIT

Assembly, Integration and Acceptance Testing (including development of the AIT plan), will be conducted in three stages:

a) **Camera Sub-system AIT**

- The camera sub-system will be assembled and integrated at the AAO North Ryde Facility (see Table 2- for draft plan);
- The camera will be verified against the High Level Requirements at the AAO North Ryde Facility.

b) **Camera to Telescope Interface**

- Integration of the camera to the telescope will be conducted at a suitable location to be defined within Australia;
- The camera to telescope interface will be verified against the High Level Requirements at a suitable location to be defined within Australia.

c) **Commissioning**

- Final on-site installation and commissioning of the camera and telescope (likely to be shipped as separate units) will occur in Antarctica, following a detailed Commissioning Plan.

**Table 2- Draft AIT Plan**

| WBS | SUB-SYSTEM | TASK | RESPONSIBLE | RESOURCE | EQUIPMENT REQUIREMENTS |
|---|---|---|---|---|---|
| 3.0 | OPTO-MECHANICS | lens verification | optical engineer | RZ | TBD |
| | | installation lens to lens cell | optical engineer | RZ | clean room, lens alignment station |
| | | installation lens assemblies into barrel | optical engineer | RZ | clean room |
| | | assembly of lens system | optical engineer | RZ | clean room, point source microscope |
| | | cold test of lens system | optical engineer | RZ | clean room, vacuum pump |
| 4.0 | DETECTOR & CONTROLLER | integrate detector with detector assembly | mechanical engineer + detectior engineer | VC+ DM | clean room |
| | | integrate filter into detector assembly | mechanical engineer + detectior engineer | VC+ DM | clean room |
| | | integrated detector asssembly into cryostat | mechanical engineer + detectior engineer | VC+ DM | clean room |
| | | internal wiring of detector system | electronics engineer | SM | clean room |
| | | electrical interface to detector controller | electronics technician | SM/RM | clean room |
| | | software interface to detector controller | electronics + software engineer | SM/RM | |
| | | cool down cryostat | electronics + software engineer | VC+ DM | clean room, vacuum pump |
| | | temperature test cryostat | mechanical engineer + detector engineer | VC+ DM | |
| | | detector test | detector engineer | DM | |
| | | adjust conductivity of cold strap and retest | mechanical engineer + detector engineer | VC+ DM | clean room, vacuum pump, workshop |
| | | interface detector controller to instrument controller | electronics + software engineer | UNSW + MV | |
| | | initial detector read tests | electronics + software engineer | UNSW + MV | |
| | | controller configuration | detector engineer | DM | |
| | | assembly of instrument controller unit | electronics technician | UNSW | electronics lab kit |
| | | install software and test of instrument controller unit | electronics + software engineer | UNSW | |
| 5.0 | CRYOSTAT SYSTEM | ultrasonic cleaning components | mechanical technician | NP | ultrasonic bath and clean room |
| | | assembly cryostat and cooler | mechanical technician | NP | clean room, tools |
| | | wiring of cooling system | electronics technician | SM | clean room, electronics lab kit |
| | | leak test of cryostat | mechanical technician | NP | clean room, vacuum pump, Helium leak detector |
| | | cold test of cryostat | mechanical technician | NP | clean room |
| | | modifications as required | mechanical engineer + technician | NP + VC | mechanical workshop |
| | | interface cryostat controller to instrument controller | electronics + software engineer | UNSW + MV | |
| | | assembly focus mechanisms | mechanical technician | NP | clean room |
| | | wiring of focus mechanisms | electronics technician | SM/RM | clean room |
| | | test of focus mechanisms | mechanical technician | NP | clean room |
| | | cold test of focus mechanisms (in cryostat) | mechanical technician | NP | clean room, vacuum pump |
| | | modify as required | mechanical technician | NP | mechanical workshop |
| | | interface mechanism controller to instrument controller | electronics + software engineer | UNSW + MV | |
| 8.0 | AIT | camera optical and alignment tests | instrument scientist | JZ | |
| | | camera full detector characterisation | instrument scientist | JZ | dark room |
| | | camera controller optimisation | detector engineer | DM | |
| | | camera environmental tests | mechanical engineer | VC | environmental chamber |
| | | telescope set-up | telescope engineer | NIAOT | automated dome |
| | | install instrument on telescope | instrument scientist | JZ | automated dome |
| | | interface telescope and instrument | electronics/software engineer | UNSW | automated dome |
| | | on-sky tests | instrument + telescope scientist | JZ + NIAOT | automated dome |

## 2.4 Design trade-offs

The following trade-offs will be considered:

#### 2.4.1 Detector Array & Controller

a) H2RG Focal Plane Array with cryogenic SIDECAR ASIC focal plane controller and Data Acquisition Module supplied by *Teledyne* (US). Detector mounting components may be supplied by *GL Scientific* (US). All items are ITAR restricted.

- Baseline is Engineering Grade A (EG-A) H2RG (2048 x 2048 x 18 µm) device: has at least a 1024 x 1024 science region conforming to the Science Grade specifications.
- Alternative option is Science Grade (SG) H2RG (2048 x 2048 x 18 µm).

b) Focal Plane Array supplied by *Selex ES* (UK) with Leach Controller supplied by *UKATC* – United Kingdom Astronomy Technology Centre (UK).

- Baseline is single 1024 x 1280 x 15 µm device;
- Alternative is mosaic of 2 or 3 of the baseline chips.

#### 2.4.2 Telescope Interface

a) **Telescope location**

- Preferred option is Chinese Kunlun station at Dome A;
- Alternatives (due to ITAR restrictions) are the US Amundsen-Scott South Pole station or the French-Italian Dome C station.

b) **Telescope/instrument integration**

- Instrument to Telescope integration location in Australia must be identified.

### 2.5 Outside Scope

The following activities are not within the scope of this project but are essential components:

#### 2.5.1 AST3-NIR telescope & telescope control system.

To be provided by NIAOT.

#### 2.5.2 Deployment & logistics to and within Antarctica

To be provided by PRIC or NSF OPP or IPEV.

#### 2.5.3 PLATO power supply

The existing PLATO-A power supply module does not provide sufficient power for AST3-1, AST3-2, and AST3-NIR and instrumentation. A new module is required – likely dedicated to AST3-NIR+instrument. This is currently unfunded.

#### 2.5.4 Operations

Observatory and telescope operations are not included within the project scope. To be provided by NAIOT+UNSW.

#### 2.5.5 Survey program

Development and management of the science cases and observing program to be provided by science team(s) coordinated by Lead Investigator.

#### 2.5.6 Data pipeline

Under this project a functioning software/control system will be provided with limited capability to transfer data or for image analysis. A more sophisticated on-site data reduction pipeline is not currently assigned or funded.

# 3 COSTING & SCHEDULE

## 3.1 Budget Estimate

Table 3- summarises the breakdown budget estimation for the instrument by sub-system. Table 3- details the funding source(s).

**Table 3- Sub-system Budget Allocation**

| WBS | SUB-SYSTEM | AAO Hours | Labour | Material | Total |
|---|---|---|---|---|---|
| 1.0 | SYSTEMS & MANAGEMENT | 648 | $64,488 | $57,255 | **$121,743** |
| 2.0 | INTERFACES | 90 | $9,040 | $0 | **$9,040** |
| 3.0 | OPTO-MECHANICS | 668 | $62,331 | $131,000 | **$193,331** |
| 4.0 | DETECTOR & CONTROLLER | 324 | $33,159 | $428,800 | **$461,959** |
| 5.0 | CRYOSTAT SYSTEM | 1,275 | $122,051 | $165,300 | **$287,351** |
| 6.0 | CONTROL SYSTEM | 480 | $46,203 | $20,000 | **$66,203** |
| 7.0 | SOFTWARE | 684 | $70,648 | $0 | **$70,648** |
| 8.0 | AIT | 1,455 | $136,827 | $4,000 | **$140,827** |
| | Sub-Total | 5624 | $544,747 | $806,355 | $1,351,102 |

**Table 3- Funding source(s)**

| Source | AUD ($k) |
|---|---|
| ARC LIEF grant | 760 |
| ANU | 10 |
| AAO | 430 |
| TAMU | 50 |
| UNSW | 50 |
| USyd | 50 |
| SUT | 0 |
| **TOTAL** | **1,350** |

## 3.2 Scheduled Milestones

Schedule milestones are listed in Table 3- below.

**Table 3- Anticipated Scheduled Milestones**

| | **Milestone Completion** | |
|---|---|---|
| 1 | Preliminary discussions with DoS re: ITAR | January 2015 |
| 2 | Project Kick-off (Meeting in Nanjing) | March 2015 |
| 3 | Project Plan Sign-off | September 2015 |
| 4 | Detector & Interface Specification | September 2015 |
| 5 | High Level Requirements Sign-off | September 2015 |
| 6 | RFQ Detector | September 2015 |
| 7 | Detector Trade-off | October 2015 |
| 8 | Contract Negotiation (Detector) | October 2015 |
| 9 | Execution of AAO/SUT Contract | October 2015 |
| 10 | Purchase Order and Export License (Detector) | December 2015 |
| 11 | Preliminary Design Review | April 2016 |
| 12 | Optics Procurement | April 2016 |
| 13 | Procurement Lead-time (Detector) | December 2016 |
| 14 | Telescope shipped to AAO Facility | December 2016 |
| 15 | Float Procurement Lead-time (Detector) | January 2017 |
| 16 | AIT @ AAO Facility | Feb. – June 2017 |
| *N/A* | *Schedule Float* | *~4 months* |
| 17 | Camera Pre Delivery Review | Late 2017 |
| 18 | Shipping to Antarctica | November 2017 |
| 19 | Commissioning | January 2018 |
| 20 | Science Survey commences | February 2018 |

## 3.3 Project Stages and Reviews

Consistent with similar sized instrument projects at the AAO, there will be no formal external reviews. A series of internal reviews will be held as defined in the schedule milestones in Table 3-. Reviews will involve a subset of: the LIEF team, the AAO/SUT/UNSW project team, and representatives from the NIAOT telescope team as required.

## 3.4 Export Control

The *Teledyne* H1RG and H2RG detectors and ASIC SIDECAR controllers are listed as restricted items on the United States munitions list and therefore export is controlled via ITAR. Some aspects of the mounting components or procedure provided by *GL Scientific* may also be ITAR restricted.

A DSP5 Hardware licence & TAA technical information exchange agreement licence must be obtained from the US Department of State (DoS) prior to export. Generally, it is difficult to obtain the necessary approval to export to any country, such as China, on the embargoed list.

A document detailing the export plan "*AST_PLN_003 AST3-NIR Export Plan"* was sent to Teledyne in December 2014. Teledyne has subsequently had discussions with DoS regarding the intended use of the detector based on this document. License application must occur after purchase order /contract in place, and can take many months.

Within Australia, the Defence Trade Control Act 2012 (currently in a two-year transition period) will be implemented after April 2016. Under this Act, there may be implications for re-export of restricted technologies to China or Antarctica. These restrictions will be investigated further by the AAO, and any necessary licenses applied for.

Export from the UK is also subject to export control. The Selex ES devices (and Leach controllers) are graded as unclassified. A license for export is required and can be rejected (although there is precedence for export of these items to China).

# 4 PRELIMINARY RISK ASSESSMENT

At this stage the key risks identified, with impact and mitigation strategy, are:

### 4.1.1 Export Control

- US or Australian export license (*Teledyne*) for Dome A denied → project delay → move project to South Pole or use non-US devices;
- US or Australian export license (*Teledyne*) for South Pole denied → project delay → use non-US devices;
- Deployment (Dome A) not approved by PRIC → project delay;
- Deployment (South Pole) not approved by US NSF → project delay → resubmit grant;

### 4.1.2 Programmatic

- Detectors (long lead item) are delayed → project delay → prioritise detector work;
- Power module not funded → replace AST3-1 and AST3-2 or deploy to South Pole → apply for funding early;
- Poor communication between partners → mistakes in interfaces → regular meetings and formal interface documentation.

### 4.1.3 Technical

- Vacuum leakage → project delay or loss of data → design, analysis, and testing;
- Detector damaged during travel → project delay or data compromised → mount design, packaging (vibration isolation) design;

- Optics misaligned during travel ▭ project delay ▭ mount design, packaging (vibration isolation) design;
- Detector performance issues (*Selex*) ▭ project delay or data compromised ▭ comprehensive system tests and detailed specification;
- Leach controller noise performance (*Selex*) ▭ project delay or data compromised ▭ comprehensive system tests and detailed specification;
- Controller or acquisition unit thermal issues ▭ project delay or data compromised ▭ design of enclosure.

# 5 DRAFT REVISION HISTORY

| Revision | Date | Author | Comments |
|---|---|---|---|
| 0.1 | 21 Dec. 2013 | JL | Initial draft outline |
| 0.2 | 25 Dec. 2013 | JL | Revision |
| 0.3 | 27 Nov. 2014 | JT | Review and include schedule and budget |
| 0.4 | 1 Dec. 2014 | JL | Minor revision |
| 0.5 | 4 Dec. 2014 | JM | Revise schedule |
| 0.6 | 5 Dec. 2014 | JL | Add Dome C as option, revise review section |
| 0.7 | 10 Dec 2014 | JL | Include comments by KG |
| 0.8 | 14 May 2015 | JT | Updated (budget, project team, detectors, milestones) |
| 0.9 | 20 Aug. 2015 | JT | Updated (during requirements review meeting) |
| 0.10 | 26 Aug. 2015 | JT | Updated to reflect contractual arrangements |
| 0.11 | 27 Aug 2015 | JL | Revision |
| | | | |